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PATENT COOPERATION TREATY

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Artcle 36 and Rule 70)

Applicant's or agent's file reference NOP80004PCT	FOR FURTHER ACTION	See Form PCT/IPEA/416
International application No. **PCT/KR2004/003243**	International filing date *(day/month/year)* **10 DECEMBER 2004 (10.12.2004)**	Priority date *(day/month/year)* 12 DECEMBER 2003 (12.12.2003)

International Patent Classification (IPC) or national classification and IPC

G01N 21/37(2006.01)i

Applicant

ELT INC. et al

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 4 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. ☒ (sent to the applicant and to the International Bureau) a total of 11 sheets, as follows:
      ☒ sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
      ☐ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.
   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) _____, containing a sequence listing and/or tables related thereto, in electronic form only, as indicated in the Supplemental Box relating to Sequence Listing (see Section 802 of the Administrative Instructions).

4. This report contains indications relating to the following items:
   - ☒ Box No. I Basis of the report
   - ☐ Box No. II Priority
   - ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - ☐ Box No. IV Lack of unity of invention
   - ☒ Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - ☐ Box No. VI Certain documents cited
   - ☐ Box No. VII Certain defects in the international application
   - ☐ Box No. VIII Certain observations on the international application

Date of submission of the demamd	Date of completion of this report
12 OCTOBER 2005 (12.10.2005)	28 MARCH 2006 (28.03.2006)

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Form PCT/IPEA/409 (cover sheet) (April 2005)

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/KR2004/003243

Box No. I Basis of the report

1. With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.

☒ This report is based on translations from the original language into the following language English, which is the language of a translation furnished for the purposes of:

- ☐ international search (under Rules 12.3 and 23.1(b))
- ☒ publication of the international application (under Rule 12.4)
- ☐ international preliminary examination (under Rules 55.2 and/or 55.3)

2. With regard to the **elements** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this reort as "originally filed" and are not annexed to this report):*

☐ the international application as originally filed/furnished

☒ the description:
pages 1-3,8-17,20-25,27 as originally filed/furnished
pages* 4,6,7,18,19,26 received by this Authority on 23/11/2005
pages* _____ received by this Authority on _____

☒ the claims:
pages 28,33 as originally filed/furnished
pages* _____ as amended (together with any statment) under Article 19
pages* 29,30,30/1,31,32 received by this Authority on 23/11/2005
pages* _____ received by this Authority on _____

☒ the drawings:
pages 1/29-29/29 as originally filed/furnished
pages* _____ received by this Authority on _____
pages* _____ received by this Authority on _____

☐ the sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing.

3. ☒ The amendments have resulted in the cancellation of:

- ☒ the description, pages 5
- ☒ the claims, Nos. 18
- ☐ the drawings, sheets _____
- ☐ the sequence listing *(specify)* : _____
- ☐ any table(s) related to sequence listing *(specify)* : _____

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).

- ☐ the description, pages _____
- ☐ the claims, Nos. _____
- ☐ the drawings, sheets _____
- ☐ the sequence listing *(specify)*: _____
- ☐ any table(s) related to sequence listing *(specify)* : _____

** If item 4 applies, some or all of those sheets may be marked "superseded."*

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	YES
	Claims	NO
Inventive step (IS)	Claims	YES
	Claims	NO
Industrial applicability (IA)	Claims	YES
	Claims	NO

2. Citations and explanations (Rule 70.7)

1. Prior Art

Reference is made to the following documents:

D1: US 6194735 B1 (HANS GORAN EVALD MARTIN) 27 Feb. 2001
D2: WO 9941592 A1 (HANS,GORAN EVALD MARTIN) 19 Aug. 1999
D3: US 5973326 A (MICHAEL P., CHELMSFORD; ALAN M. D., MALDON) 26 Oct. 1999
D4: US 5170064 A (ATOMIC ENERGY OF CANADA LIMITED) 8 Dec. 1992
D5: US 5116120 A (VOLKSWAGEN AG) 26 May 1992
D6: US 4189236 A (COULTER ELECTRONICS, INC.) 19 Feb. 1980

2. Regarding Novelty

D1 is considered to be the most relevant state of the art.

The common technical feature of claims 1, 11, 16, and 24 is that two opposing concave mirrors are used to form an optical cavity. Said claims differ from D1 in that they use two mirrors, whereas D1 uses three opposing concave light reflecting wall-parts (11, 12, and 13). Therefore, the subject matter of claims 1, 11, 16 and 24 is considered to be new (Art. 33(2) PCT).

The subject matter of claims 2-10, 12-15, 17, 19-23, and 25 which are dependent claims is also considered to be new (Art. 33(2) PCT).

3. Regarding Inventive Step

3.1 Concerning Claims 1-10

The subject matter of claim 1 is an optical gas sensor comprising a gas chamber, a gas opening, an optical source and an infrared sensor. The optical gas sensor of claim 1 is characterized in that the curvature of the opposing concave mirrors are designed for the incident light to be parallel to the axis or to pass through the focus.

(Continued on Supplemental Sheet.)

Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of:

Box V.

The subject matter of D1 is an optical gas sensor which belongs to the same technical field as the present invention. D1 comprises a gas cell (1), openings (6 and 7), a light source (2a) and wall parts (11, 12, 13). Both D1 and claim 1 comprise openings, an optical source, and a sensor, and the gas cell of D1 corresponds to the gas chamber of claim 1.

There are two technical differences between claim 1 and D1: 1) claim 1 comprises two concave mirrors, whereas D1 comprises three concave reflecting mirrors; and claim 1 includes parallel light paths, whereas D1 does not.

The parallel light paths of claim 1 would not be obvious from D1 (see fig. 8), because D1 does not teach or fairly suggest said feature. Therefore, the subject matter of claim 1 seems to involve an inventive step (Art. 33(3) PCT).

Dependent claims 2-10 referring to claim 1 are also considered to involve an inventive step (Art. 33(3) PCT).

3.2 Concerning Claims 11-15

The technical feature of claim 11 that "each of the concave mirrors has the shape of a portion of a parabola or a circular arc" would not be obvious from D1 because D1 does not teach or fairly suggest said feature. Therefore, the subject matter of claim 11 seems to involve an inventive step (Art. 33(3) PCT).

Dependent claims 12-15 referring to claim 11 are also considered to involve an inventive step (Art. 33(3) PCT).

3.3 Concerning Claims 16-17, 19-25

The technical features of claims 16 and 24 that "the cross section of the concave mirror is a circular arc," and "the two circular arcs have different radius from each other" would not obvious from D1 because D1 does not teach or fairly suggest said features. Therefore, the subject matter of claims 16 and 24 seems to involve an inventive step (Art. 33(3) PCT).

Dependent claims 17 and 19-23 referring to claim 16 and dependent claim 25 referring to claim 24 are also considered to involve an inventive step (Art. 33(3) PCT).

However, since it is difficult to produce such a system and a step motor is needed for the rotation of the reflective mirror, it cannot be easily used in a small, portable and easy-to-use gas analyzer.

Still another method was disclosed in PCT/SE97/01366 (WO 98/09152) titled "GAS SENSOR" proposed by Martin. In order to provide a relatively long optical path in an optical cavity having a limited size, the method arranges three concave mirror surfaces as illustrated in Fig. 4. In other words, the gas sensor proposed by Martin comprises three elliptical concave surfaces, and it has an optical gas sensor cell structure, employing the White's cell concept of setting the focus of reflected light from each concave surface on or adjacent to the opposite reflection surface.

However, this gas sensor cell having three reflection surfaces is complex. Also, since the incident light, which is radiated from an optical source located on the surface of a main mirror (a mirror of one body) through an optical cavity, may have slight changes in its incident angle, it was difficult to determine the appropriate location of optical sensor.

There are four kinds of optical cavities that have been applied to existing NDIR gas sensor systems.

First, as disclosed in U.S. Patent No. 5,444,249 of Jacob Y. Wong, which was issued on August 22, 1995, there is a square type or a cylindrical tube type having one infrared (IR) source and one light detector.

Next, as disclosed in U.S. Patent No. 6,067,840 invented by Mahesan Chelvayohan and issued on May 30, 2000 or as disclosed in the Article titled "An implementation of NDIR type CO_2 gas sample chamber and measuring hardware for capnograph system in consideration of time response characteristics" in *Journal of Korean Sensor Society*, vol. 5, no.5, pp. 279-285, 2001 by I.Y.Park, *et al.*, there is a type comprising one light detector and two IR optical sources for thermal aging compensation.

Third, what is disclosed in the Article titled " CO_2/H_20 Gas Sensor Using Tunable Fabry-Perot Filter with Wide Wavelength Range" in the IEEE International Conference on

MEMS, pp. 319-322, 2003 by Makoto Noro, *et al.* is a type using a cylindrical tube optical cavity and applying a Fabry-Perot filter for selecting target gas wavelength.

Fourth, what is disclosed in PCT/SE97/01366 (WO 98/09152) titled "Gas Sensor" dated March 5, 1998 by Martin Hans, *et al.* is a type comprising three concave mirrors in order to increase the light path within a chamber of a small volume.

Detailed Description of the Invention

The present invention has been conceived in order to resolve the aforesaid problems. The object of the present invention is to maximize the length of the optical path and to provide an optical gas sensor having a broad measurement ranges with an optical cavity (or a gas chamber) structure that can be easily designed.

Also, the present invention provides a new optical cavity structure for a new optical gas sensor cell, and presents a new gas sensor based on the CO_2 concentration measurement experiment result of a sensor employing such an optical cavity.

Fig. 12 is a perspective view of the optical gas sensor reviewed in the above Figs. 8-11 according to one embodiment of the present invention.

Fig. 13 is a top plane view of an optical gas sensor according to another embodiment of the present invention. Fig. 14 is a sectional view of A-A' of the optical gas sensor illustrated in Fig. 13.

The structure of the optical gas sensor illustrated in Fig. 13 is nearly the same as that of the optical gas sensor of the above Figs. 8-12 except that two mirrors forming a gas chamber wall are configured as parabolas instead of circular arcs.

In other words, the gas chamber wall of the optical gas sensor illustrated in Fig. 13 uses two opposing parabolic reflective mirrors having a common focus but different focal distance. Also, a gas vent (45) is curved in the direction of gravity to prevent internal pollution of the gas chamber.

Upon reviewing the operation principle of the optical gas sensor illustrated in Figs. 13 and 14, infrared light radiated through an infrared lamp (95) passes via an optical outlet (85) and a parabolic mirror (55), and is entered into the gas chamber.

The incident light is entered toward the common focus of a first parabolic reflective mirror (25) and a second parabolic reflective mirror (35), reflected by the first and second parabolic reflective mirrors (25, 35) and converged. The light intensity is measured at an infrared sensor (65).

Further object of the present invention is to produce an optical cavity for non-

dispersive infrared gas sensor, comprising two concave mirrors which are opposed to each other, of which the section is a circular arc, of which the central point is located on the same axis, and which are optically closed except for an inlet for establishing an optical source, an outlet for establishing a light detector and gas inlet/outlets.

Also, further object of the present invention can be achieved by a non-dispersive infrared gas sensor comprising an optical source for irradiating infrared; a light detector for ultimately detecting light from the optical source; an optical cavity which is formed by two opposing concave mirrors of which the cross-section is a circular arc, of which the central point is located on the same axis, and which are optically closed except for the inlet for establishing an optical source and the outlet for establishing a light detector and gas in/outlets; an optical modulating part having a pulse modulation time of 200-600 ms and turn-off time of 2, 2.5 and 3 sec. for controlling the light irradiated from the optical source; and an amplification part for amplifying an electrical signal from the light detector.

Hereinafter, further aspects of the present invention will be further explained with reference to the drawings illustrating another embodiments of the present invention.

Basically, the optical cavity of the present invention is produced by circular arcs. The central point of the two circular arcs exists on the same axis.

Also, the embodiments of the present invention design the central point of each circular arc to be identical with the middle point of the straight line going from one circular arc to the other circular arc (the two centers of two circular arcs exist on the same straight line). The reason thereof is for irradiated light under a certain condition to be able to pass via a certain point on the same straight line (if the feature of a circular arc is applied identically with a parabola, the circular arcs are designed to pass via an identical focus). The reason for endowing this condition is, for example, to ensure the characteristic of a

discharge of the absorbed heat is not conducted completely and the lifetime of the optical source becomes shortened.

Fig. 26 illustrates changes of the output voltage according to the change of CO_2 gas concentration in the above embodiment of the present invention. It shows normalized output signals of the NDIR sensor module when the CO_2 gas concentration increases between 100-2,000 ppm. The normal output signal exhibits the maximum change when the infrared pulse modulation time is 200 ㎳. As the modulation time increases between 300-500 ㎳, the normal output signal is considerably reduced.

Meanwhile, the maximum voltage difference is shown at 500 ㎳ of pulse duration time, but simultaneously the reference voltage slightly increases. The change of the output voltage becomes maximum at 200 ㎳ of pulse duration time, and exhibits 18,000 times of amplification gain. At this time, the turn-off time of the infrared optical source is 3 sec.

Although the present invention has been described with reference to particular embodiments of the NDIR gas sensor and the optical cavity, the description is only an example of the invention's application and should not be taken as limiting the scope of the present invention. Various adaptations and combinations of simulations and the embodiments disclosed are within the scope of the invention as defined by the appended claims.

For example, in order to obtain the parallel light of the present invention, another method of producing a parabolic type mirror in an optical cavity can be employed for production of a cost-effective optical cavity, and the present invention can be implemented using laser source having a predetermined wavelength without the use of the IR lamp from Gilway™.

5. The optical gas sensor according to claim 2, wherein the gas vent is advantageously curved downward or equipped with a detachable cap.

6. The optical gas sensor according to claim 1, wherein the surface of the concave mirror is plated by or deposited with gold.

7. The optical gas sensor according to claim 2, wherein the gas chamber contains a parabolic reflecting mirror integrally formed with the support plate of the gas chamber adjacent to the infrared optical source formed at the support plate.

8. The optical gas sensor according to claim 7, wherein a light outlet for projecting at least a part of the infrared light from the infrared optical source is formed on the support plate of the gas chamber.

9. The optical gas sensor according to claim 7 or 8, wherein the infrared optical source is disposed on the focus of the parabolic mirror.

10. The optical gas sensor according to claim 2, wherein the support plate of the gas chamber is attached with a height compensation structure for compensating the inclination of the support plate due to the height of the infrared optical source.

11. An optical gas sensor comprising a gas chamber for housing a sample gas; a gas opening for injecting the sample gas into the gas chamber or for exhausting the sample gas from the gas chamber; an optical source for projecting light toward the sample gas;

and an optical sensor for sensing the intensity of the light which has passed through the sample gas, characterized in that:

the wall of the gas chamber is composed of two opposing concave mirrors having different focusing distances but a common focus, and that each of the concave mirrors has a shape of a portion of a parabola or a circular-arc.

12. The optical gas sensor according to claim 11, wherein the gas opening comprise a gas vent located at a certain wall of the gas chamber and a plurality of gas diffusion halls disposed on the lower or upper support plate of the gas chamber.

13. The optical gas sensor according to claim 11 or 12, wherein the plurality of gas diffusion halls are covered by gas filters.

14. The optical gas sensor according to claim 11, wherein the surface of the concave mirror is plated by or deposited with gold.

15. The optical gas sensor according to claim 12, wherein the gas chamber contains a parabolic reflecting mirror formed so that the parabolic reflecting mirror causes the incident light from the infrared source to propagate in parallel with the horizontal support plate of the gas chamber.

16. An optical cavity for a non-dispersive infrared sensor, characterized in that: the optical cavity is formed by two opposing concave mirrors, the cross-section of the concave mirror is a circular arc, the two circular arcs have different radius from each

other, the central points of the two circular arcs exist on the same axis, and the optical cavity is optically closed except for holes for optical source,

optical detector, gas vent and gas diffusion.

17. The optical cavity according to claim 16, wherein the central point of each circular arc coincides with the middle point of the straight line going from one circular arc to the other circular arc.

18. Cancelled

19. The optical cavity according to claim 16 or 17, wherein the central point of the circular arc having a longer radius exists outside of the circular arc having a shorter radius, and the central point of the circular arc having a shorter radius exists inside of the circular arc having a longer radius.

20. The optical cavity according to claim 19, wherein the optical source and the optical detector are located on a different circular arc, and an incident light from the optical source is irradiated in parallel with the axis on which the central points of the two circular arcs are located, reflected once on each of the circular arc and detected by the optical detector.

21. The optical cavity according to claim 20, wherein the parallel light irradiated from the optical source focuses on the circular arc where the optical detector is located.

22. The optical cavity according to claim 17, wherein the optical source and the

optical detector are located on the same circular arc, and an incident light from the optical source is reflected odd number of times on each of the circular arc and detected by the optical detector.

23. The optical cavity according to claim 22, wherein the incident light from the optical source incidents to or adjacent to a center of the optical cavity, repeats convergence and divergence during the plurality of reflections and reaches the optical detector, and wherein the cross-sectional area of the light reaching the circular arc on which the optical detector is located is larger than that of the light irradiated from the optical source.

24. An optical cavity for a non-dispersive infrared sensor comprising:

an optical source for irradiating infrared light;

an optical detector for ultimately detecting the infrared light from the optical source;

an optical cavity formed by two opposing concave mirrors, wherein the cross-section of the concave mirror is a circular arc, the two circular arcs have different radius from each other, the central points of the two circular arcs exist on the same axis, and the optical cavity is optically closed except for holes for optical source, optical detector, gas vent and gas diffusion;

an optical modulating means for controlling the infrared light irradiated from the optical source, wherein the optical modulating means has a pulse modulation time of 200-600 ms and turn-off time of 2 sec., 2.5 sec. and 3 sec.; and

an amplification means for amplifying an electrical signal from the optical detector.